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PETN Sample Preparation Safety Limits

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Disclaimer

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PETN Sample Preparation Safety Limits

Scope:
27 psi has been determined to be the maximum allowable pressure for contact operations with PETN at LLNL. Pressures above this limit can be tested, but samples must be prepared via remote handling operations. This document summarizes the safety review and discussion that took place at LLNL to define this pressure limit.

Background:
PETN is a secondary explosive chosen as the threshold between primary and secondary explosives for operations at LLNL. Any explosive with an impact, electrostatic, or friction threshold less than that of PETN is considered a primary material. Any operation with a primary explosive at LLNL requires a Peer Review[1] before the work can be conducted. Thus, PETN is considered the most sensitive secondary explosive that is handled at LLNL.

Pressing of explosives at LLNL, both secondary and primary, can be performed at pressures exceeding 20,000 psi. Such pressing is done as a remote operation (i.e. activity performed with all personnel safely and physically separated from the explosives) and often requires an additional Peer Review. These increased safety precautions are warranted as a large fraction of explosive accidents involve pressing operations; further, the mechanisms behind the accidents are not completely understood. LLNL has historically chosen to err on the side of caution, and in doing so, has maintained an exemplary explosives safety record.

Contact operations with an explosive (i.e., activities performed with a person present) are permitted for normal handling of secondary explosives where significant energy is not introduced by the explosive handler. This includes hand-tamping or light compaction with nonmetal tools. As explosives scientists on the NEXESS Center team at LLNL undertook sample preparation with PETN in support of NEXESS activities and IDD efforts, a question arose during packing sample containers: *When is it appropriate to consider the packing a standard contact operation, and when should the packing be required to be carried out remotely*?

Approach:
The ability to predictively address this question both accurately and confidently enough to set safety protocols does not currently exist. As it is difficult to determine the cause of explosive-related accidents involving, it is difficult to predict when remote handling will be necessary. It is equally challenging to evaluate the answer through experimentation, as the experimental determination of probability for very infrequent events is daunting at best. In the absence of a modeling or experimental solution, we turned to expert judgment and experience coupled to a conservative approach.

Several highly trained explosive handlers at LLNL, many with decades of hands-on work experience, were asked what their practice would be for hand-packing PETN in a contact operation. The historical packing method at LLNL for the preparation of samples for cylinder tests (packed to different densities) was seen as a valid starting point to begin this discussion. In order to prepare these samples, the explosive is placed into a copper cylinder and packed using an LLNL-designed tamping rod. This rod has an aluminum shaft with a Teflon disk at the base that contacts the explosive, and a T-shaped handle at the top to assist in manual manipulation. Historically, the preparation of samples for a cylinder test has been standardized to ensure that a reproducible force can be applied with hand pressure or physical weights to the tamping rod. Such samples have been historically prepared using weights up to about 30 lbs on the T-shaped handle – the maximum weight that an average operator could safely lift and that very experienced explosive handlers felt was appropriate for contact compaction.

When developing methods for specimen preparation for NEXESS and in support of IDD, the tamping rod and setup of packing samples for cylinder tests were duplicated, as the method had been historically successful and approved. The tamping rod was used to prepare 'heavy tamped' samples by applying a 30 lb weight to the T-shaped handle resulting in 27 psi of pressure. The reviewing LLNL explosive handlers agreed that a packing pressure of 27 psi was within the safe handling standards for PETN (small scale safety data is included in the supporting information below). The decision was made that any compaction beyond the range of 'normal hand packing' should be considered pressing and therefore conducted remotely. Such packing has been defined as only using the force and actions that one average person could apply to prepare a sample reproducibly and with only simple tamping tools. As a result of this expert evaluation, the 27 psi limit has been defined as the limit of 'normal hand packing,' and any pressure applied above this limit must be done remotely.

This guideline is very conservative, as PETN can be, and often has been, pressed at pressures over 1000 times higher than this. However, given the poorly understood mechanisms for accidental explosions and the high consequence of accidental explosion in a contact operation, such conservatism is warranted.

If further data become available or if a reasonable modeling approach is identified, this threshold could be re-evaluated and, perhaps, relaxed in the future.

Supporting Information:
Small-scale safety testing is used to determine material response to various stimuli including impact, friction, static spark, and thermal stability. These tests provide parameters for safety in handling, and testing was completed on PETN extracted from Primacord™ 10. The results of this testing are shown in Table 1 and fall in the normal range of what is expected for the sensitivity and stability of PETN.

Table 1. Small-scale safety and thermal data

	Impact, DH_{50}	**Friction, BAM**	**Spark**	**DSC**	**CRT**
PETN extracted from Primacord™ 10	16 cm	1/10 @ 8.4 kg	0/10 @ 1.0 J	204 °C	0.01 cc/g @ 80°C
PETN reference material	15 cm	1/10 @ 6.4 kg	0/10 @ 1.0 J	203 °C	0.1-0.14 cc/0.25 g @ 120°C

DH_{50}—Type 12, 120-grit sand paper, 2.5 kg drop weight, Friction—BAM, Spark—Custom built, 500 ohm resistor in circuit, CRT-Chemical Reactivity test.

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[1] Conducting a Peer Review for experimental explosives work ensures that factors that may adversely affect the success or safety of the experiment are identified prior to commencement of such work. The Peer Review process is a thorough and objective review, by designated experts, of explosives work that involves new processes, experimental conditions or materials, or work that is otherwise required by facility or operational safety plans' procedures to undergo a Peer Review. (LLNL Environmental Safety and Health, Vol II, Park 17: Explosives and Firearms. Rev 3. UCRL-AM-133867.)